THE NATURE OF THE LATER DEFORMATIONS IN CERTAIN RANGES OF THE GREAT BASIN

CHARLES LAURENCE BAKER

The department of paleontology of the University of California has lately made three expeditions into different regions of the southwestern part of the Great Basin with the main purpose of collecting Tertiary mammalian fossils. Incidentally a considerable body of new facts relative to the deformational and physiographic history of the later Cenozoic have been gathered, and a brief summary of some of the more important of these is here presented. No greater degree of accuracy than that implied by a rapid reconnaissance can be claimed for these statements. They apply to the following sections: the southern Sierra Nevada from the vicinity of Mono Lake southward to a point beyond Tehachapi Pass; the Black Mountain Range; the Calico Mountains of the central Mohave Desert; the El Paso Mountains, a short low range running *en echelon* with the southern Sierra Nevada southwest of Walker Pass; the northern White Mountain or Inyo Range on the boundary line between Nevada and California; the northern Silver Peak Range; the northern Pilot Range; the southern Gabbs Valley Range; the Cedar Mountain Range west and northwest of Tonopah, in central western Nevada; and the intervening basins.

The main tentative conclusion reached is that the conception of the extensive development of *normal* or *gravity* block faults *of great displacement* originally advanced by Russell and LeConte, and subsequently adopted by King, is fundamentally erroneous so far as this portion of the Basin Range province is concerned. In the opinion of the writer the Basin Ranges are really mountains of tangential compression. The evidence for this view is both structural and physiographic. The block faults, first described by Gilbert, can apparently be explained in considerable proportion quite as well as "upthrusts"—in the sense in which this

term was first used by Powell and C. A. White—as by the old conception of normal or gravity faults. Such of the faults as are really of the tensional type are probably those formed by the stretching of competent brittle rock along the flanks or summits of anticlines. There is so much of very competent rock in that region, and this is so commonly deformed by fracture rather than by flexure, that faults are very greatly developed and are often of great displacement.

The key to the problem is an old erosion surface, locally approaching the condition of a peneplain. This bevels the folded strata, and these contain a fairly abundant mammalian fauna of later Tertiary age. These folded and beveled later Tertiary beds have now been found in three widely separated localities of the southwestern Great Basin, namely in central western Nevada, in the central Mohave Desert, and in a region on the border line between the Mohave Desert proper and the rest of the Great Basin. The erosion surface cut out of these beds is in places warped into synclines, which form the valleys between many Basin Ranges, and into anticlines, which form the isolated ranges. In other places it is faulted, forming grabens in the cases of Death and Owens valleys and possibly elsewhere, and in other and more numerous cases tilted blocks bounded on one side by a fault scarp. The longitudinal profile of a block-faulted range, as determined by Louderback and the writer, is essentially that of the longer axis of an anticline. From a point of maximum movement the amount of displacement gradually dies out in either direction into monoclinal flexures and finally into undisturbed strata. Some of the Basin Ranges, as first pointed out by Spurr and Ball, do not owe their present forms in any sense to faulting but are merely structural upwarps or a series of anticlines more or less modified by erosion. Many of the intermontane basins are plainly seen to be true synclinal spoon-shaped basins. Gilbert's original suggestion that many of the Basin Ranges have their greater portions buried under their own débris is true only in a limited degree, for the original bed rock is found exposed at various places from the centers to the peripheries of some basins. In many of the basins the alluvium has not buried the post-Miocene

erosion surface, the formation of which antedated the latest deformation. The processes of desert erosion and deposition in an arid climate may mantle the rock surfaces of the ranges almost to their summits, and yet give only a very thin veneer above the bed rock, as mining operations at Tonopah and elsewhere have shown. In the immediate proximity of great fault scarps, the piedmont alluvial fans are, however, usually of great thickness, as on both sides of Owens and Death valleys.

The second uplift followed the axes of the first later Tertiary deformation but it seems to have been less intense, for the non-competent later Tertiary sediments, which were intensely folded in places and even overthrust during the first deformation, have been only gently warped during the second. This fact can be determined by the shape of the deformations in the peneplain produced during the first cycle of erosion. How much of the original folding of the non-competent later Tertiary beds has been due to a movement laterally over the basement of competent rocks which may have deformed mainly by fracture, is not known.

Zones of faulting along the bases of ranges have been examined by the writer in the Calico Mountains of the Mohave Desert in the Silver Peak Range in western Nevada and on the south base of the Sierra Nevada east of Tehachapi Pass. The fault planes in these localities approach the vertical and some even overhang. There is in the Silver Peak Range a zone of faulting rather than a single plane of faulting. The upthrown side forming the scarp is made up of the more competent and more erosion-resistant rocks, while the less competent strata on the downthrown side are closely compressed and overthrust contiguous to the faulting. In the Death Valley region, where faulting has probably taken place on as great a scale as anywhere in the Great Basin, closely folded Tertiary strata, referred to the Miocene by Spurr and Ball, bound the valley side of the Funeral Range fault. It is difficult to conceive how this folding and thrusting can have been caused by tensional stresses manifested in normal faults.

Gilbert's original conception of block-faulted mountains is incontestable. Gilbert never held, to the knowledge of the writer,

that all of the ranges of the Great Basin were of the block-faulted type, nor, as far as the writer knows, did he ever express the opinion in writing that the block-faults were all the results of tensional stresses.

On the contrary, Gilbert expressly states, on pp. 61 and 62 of Vol. III, U.S. Geographical Surveys West of the 100th Meridian, the following:

> . . . . In the Appalachians corrugation has been produced commonly by folding, exceptionally by faulting; in the Basin Ranges, commonly by faulting, exceptionally by flexure. The regular alternation of curved synclinals and anticlinals is contrasted with rigid bodies of inclined strata, bounded by parallel faults. The former demand the assumption of great horizontal diminution of the space covered by the disturbed strata, and suggest lateral pressure as the immediate force concerned; the latter involve little horizontal diminution, and suggest the application of vertical pressure from below. . . . . It is, that in the case of the Appalachians the primary phenomena are superficial; and in that of the Basin Ranges they are deep-seated, the superficial being secondary; that such a force as has crowded together the strata of the Appalachians—whatever may have been its source—has acted in the Ranges on some portion of the earth's crust beneath the immediate surface; and the upper strata, by continually adapting themselves, under gravity, to the inequalities of the lower, have assumed the forms we see. Such a hypothesis, assigning to subterranean determination the position and direction of lines of uplift in the Range System, and leaving the character of the superficial phenomena to depend on the character and condition of the superficial materials, accords well with many of the observed facts, and especially with the persistence of ridges where structures are changed. It supposes that a ridge, created below, and slowly upheaving the superposed strata, would find them at one point coherent and flexible, and there produce an anticlinal; at another hard and rigid, and there uplift a fractured monoclinal; at a third, seamed and incoherent, and there produce a pseudo-anticlinal, like that of the Amargosa Range.

Spurr's general view that the present Basin Ranges owe their forms to folding modified by erosion, holds in part, but Spurr appears to have clearly recognized but one great deformation, the mid-Mesozoic, although he did mention the folding of Tertiary strata. He failed to recognize that the axes of later deformations often cut diagonally or at right angles across the axes of the mid-Mesozoic folding. The recognition of this fact was one of Louder-

back's main contributions; it was noted in several ranges by the geologists of the Fortieth Parallel Survey, and the writer has recently noted the same divergence of earlier and later axes of folding in two other Nevada ranges, the Pilot Range and the Cedar Mountain Range.

The recency of the movement to which the existing Basin Ranges owe their forms is such as to leave intact, in large measure, the superficial rocks of the lithosphere, even when these lie high in the zone that was affected by fracture during this deformation. We know this because there is still preserved much of the erosion surface developed previous to this deformation. It also happens that a large portion of this superficial rock is of a competent nature and, without any load, seems quite as likely, or more likely, to break than to fold. The Basin Ranges may very possibly have originated by tangential compression. Their present elevations and structures may be a joint product of the initial intensity of the deformative forces and of the relative resistance to deformation of the strata involved. This is a very elementary conception but is as far as the writer is willing to go on his present data.

The mid-Mesozoic deformation was apparently the most intense, the folds in the Death Valley region and in the Pilot Range being as close as those of the central Appalachians. The first later Tertiary deformation was probably on the whole less intense, although locally non-competent beds are closely crumpled and overthrust. The writer's studies have not been of such a detailed nature as clearly to separate the effects of these two movements on the older rocks. The most recent deformation is the least intense, at any rate as exhibited on the surface, but is the one which is responsible for the present orographic features of the Basin Ranges. What has happened in the zone of flow, or in the zone of combined fracture and flow, during this latest deformation, we have no means of knowing, since erosion has not yet laid bare these zones. But it is probable that in the southwestern portion of the Great Basin the competent brittle rocks at the surface or close to the surface have deformed somewhat differently from the dominantly sedimentary rocks of the Rocky Mountains, the Jura,

the California Coast Ranges, the central and northern Appalachians, the Alps, and the Himalayas, which are taken as classic types of tangentially compressed mountains.

There may be movements of mountain-making intensity in this province other than those outlined above; but these three have been found to be readily determinable. There are physiographic evidences of intermittency in the most recent uplift in central western Nevada.